FIG.5

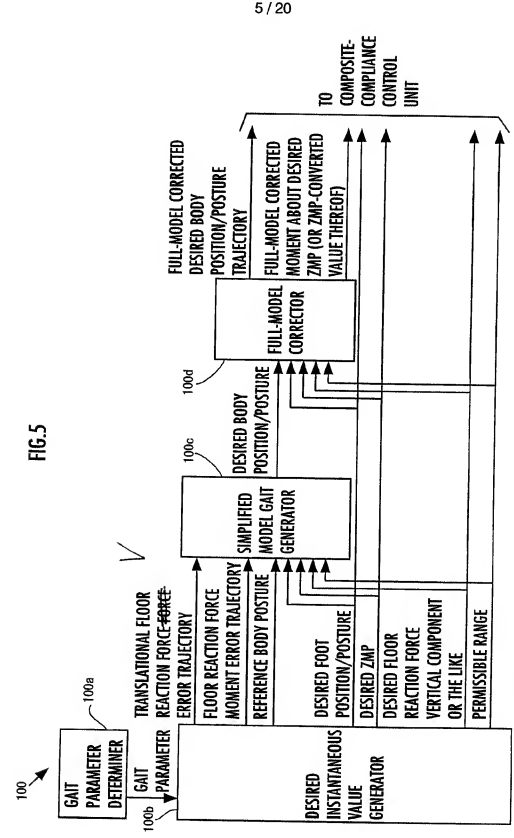

100
GAIT PARAMETER DETERMINER
100a
GAIT PARAMETER
100b
DESIRED INSTANTANEOUS VALUE GENERATOR
TRANSLATIONAL FLOOR REACTION FORCE ERROR TRAJECTORY
FLOOR REACTION FORCE MOMENT ERROR TRAJECTORY
REFERENCE BODY POSTURE
DESIRED FOOT POSITION/POSTURE
DESIRED ZMP
DESIRED FLOOR REACTION FORCE VERTICAL COMPONENT OR THE LIKE
PERMISSIBLE RANGE
SIMPLIFIED MODEL GAIT GENERATOR
100c
DESIRED BODY POSITION/POSTURE
FULL-MODEL CORRECTOR
100d
FULL-MODEL CORRECTED DESIRED BODY POSITION/POSTURE TRAJECTORY
FULL-MODEL CORRECTED MOMENT ABOUT DESIRED ZMP (OR ZMP-CONVERTED VALUE THEREOF)
TO COMPOSITE-COMPLIANCE CONTROL UNIT

FIG.10

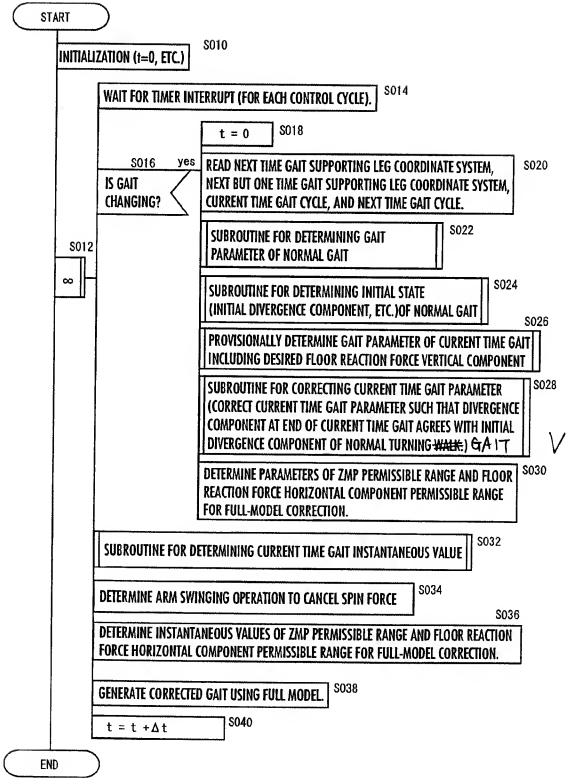

START
INITIALIZATION (t=0, ETC.)
S010
WAIT FOR TIMER INTERRUPT (FOR EACH CONTROL CYCLE).
S014
t = 0
S018
S016
yes
IS GAIT CHANGING?
READ NEXT TIME GAIT SUPPORTING LEG COORDINATE SYSTEM, NEXT BUT ONE TIME GAIT SUPPORTING LEG COORDINATE SYSTEM, CURRENT TIME GAIT CYCLE, AND NEXT TIME GAIT CYCLE.
S020
SUBROUTINE FOR DETERMINING GAIT PARAMETER OF NORMAL GAIT
S022
S012
∞
SUBROUTINE FOR DETERMINING INITIAL STATE (INITIAL DIVERGENCE COMPONENT, ETC.)OF NORMAL GAIT
S024
S026
PROVISIONALLY DETERMINE GAIT PARAMETER OF CURRENT TIME GAIT INCLUDING DESIRED FLOOR REACTION FORCE VERTICAL COMPONENT
SUBROUTINE FOR CORRECTING CURRENT TIME GAIT PARAMETER (CORRECT CURRENT TIME GAIT PARAMETER SUCH THAT DIVERGENCE COMPONENT AT END OF CURRENT TIME GAIT AGREES WITH INITIAL DIVERGENCE COMPONENT OF NORMAL TURNING ~~WALK~~) GAIT
S028
DETERMINE PARAMETERS OF ZMP PERMISSIBLE RANGE AND FLOOR REACTION FORCE HORIZONTAL COMPONENT PERMISSIBLE RANGE FOR FULL-MODEL CORRECTION.
S030
SUBROUTINE FOR DETERMINING CURRENT TIME GAIT INSTANTANEOUS VALUE
S032
DETERMINE ARM SWINGING OPERATION TO CANCEL SPIN FORCE
S034
S036
DETERMINE INSTANTANEOUS VALUES OF ZMP PERMISSIBLE RANGE AND FLOOR REACTION FORCE HORIZONTAL COMPONENT PERMISSIBLE RANGE FOR FULL-MODEL CORRECTION.
GENERATE CORRECTED GAIT USING FULL MODEL.
S038
t = t +Δt
S040
END

FIG.12

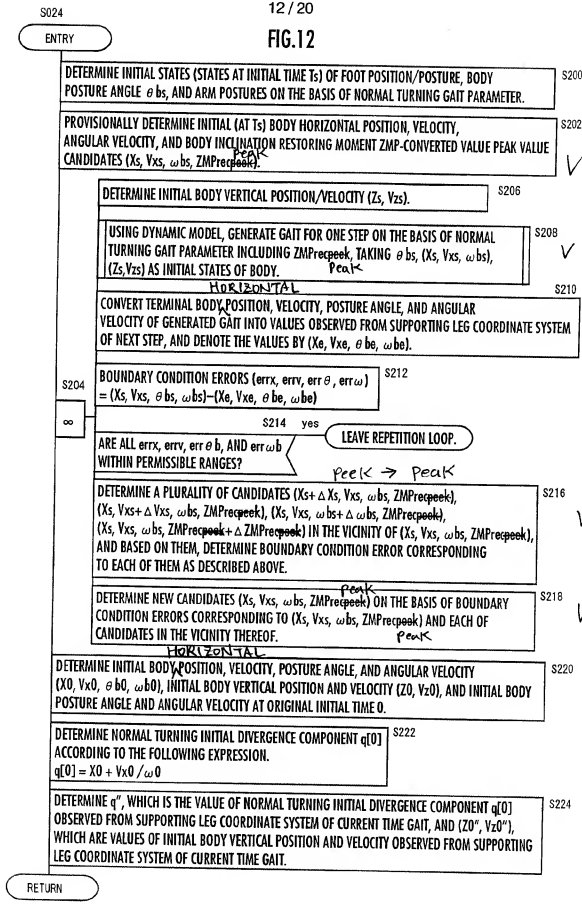

S024
ENTRY
DETERMINE INITIAL STATES (STATES AT INITIAL TIME Ts) OF FOOT POSITION/POSTURE, BODY POSTURE ANGLE θbs, AND ARM POSTURES ON THE BASIS OF NORMAL TURNING GAIT PARAMETER.
S200
PROVISIONALLY DETERMINE INITIAL (AT Ts) BODY HORIZONTAL POSITION, VELOCITY, ANGULAR VELOCITY, AND BODY INCLINATION RESTORING MOMENT ZMP-CONVERTED VALUE PEAK VALUE CANDIDATES (Xs, Vxs, ωbs, ZMPrecpeek).
S202
DETERMINE INITIAL BODY VERTICAL POSITION/VELOCITY (Zs, Vzs).
S206
USING DYNAMIC MODEL, GENERATE GAIT FOR ONE STEP ON THE BASIS OF NORMAL TURNING GAIT PARAMETER INCLUDING ZMPrecpeek, TAKING θbs, (Xs, Vxs, ωbs), (Zs,Vzs) AS INITIAL STATES OF BODY.
S208
CONVERT TERMINAL BODY POSITION, VELOCITY, POSTURE ANGLE, AND ANGULAR VELOCITY OF GENERATED GAIT INTO VALUES OBSERVED FROM SUPPORTING LEG COORDINATE SYSTEM OF NEXT STEP, AND DENOTE THE VALUES BY (Xe, Vxe, θbe, ωbe).
S210
S204
∞
BOUNDARY CONDITION ERRORS (errx, errv, errθ, errω) = (Xs, Vxs, θbs, ωbs)−(Xe, Vxe, θbe, ωbe)
S212
S214
ARE ALL errx, errv, errθb, AND errωb WITHIN PERMISSIBLE RANGES?
yes
LEAVE REPETITION LOOP.
DETERMINE A PLURALITY OF CANDIDATES (Xs+ΔXs, Vxs, ωbs, ZMPrecpeek), (Xs, Vxs+ΔVxs, ωbs, ZMPrecpeek), (Xs, Vxs, ωbs+Δωbs, ZMPrecpeek), (Xs, Vxs, ωbs, ZMPrecpeek+ΔZMPrecpeek) IN THE VICINITY OF (Xs, Vxs, ωbs, ZMPrecpeek), AND BASED ON THEM, DETERMINE BOUNDARY CONDITION ERROR CORRESPONDING TO EACH OF THEM AS DESCRIBED ABOVE.
S216
DETERMINE NEW CANDIDATES (Xs, Vxs, ωbs, ZMPrecpeek) ON THE BASIS OF BOUNDARY CONDITION ERRORS CORRESPONDING TO (Xs, Vxs, ωbs, ZMPrecpeek) AND EACH OF CANDIDATES IN THE VICINITY THEREOF.
S218
DETERMINE INITIAL BODY POSITION, VELOCITY, POSTURE ANGLE, AND ANGULAR VELOCITY (X0, Vx0, θb0, ωb0), INITIAL BODY VERTICAL POSITION AND VELOCITY (Z0, Vz0), AND INITIAL BODY POSTURE ANGLE AND ANGULAR VELOCITY AT ORIGINAL INITIAL TIME 0.
S220
DETERMINE NORMAL TURNING INITIAL DIVERGENCE COMPONENT q[0] ACCORDING TO THE FOLLOWING EXPRESSION.
q[0] = X0 + Vx0 / ω0
S222
DETERMINE q", WHICH IS THE VALUE OF NORMAL TURNING INITIAL DIVERGENCE COMPONENT q[0] OBSERVED FROM SUPPORTING LEG COORDINATE SYSTEM OF CURRENT TIME GAIT, AND (Z0", Vz0"), WHICH ARE VALUES OF INITIAL BODY VERTICAL POSITION AND VELOCITY OBSERVED FROM SUPPORTING LEG COORDINATE SYSTEM OF CURRENT TIME GAIT.
S224
RETURN

FIG.17

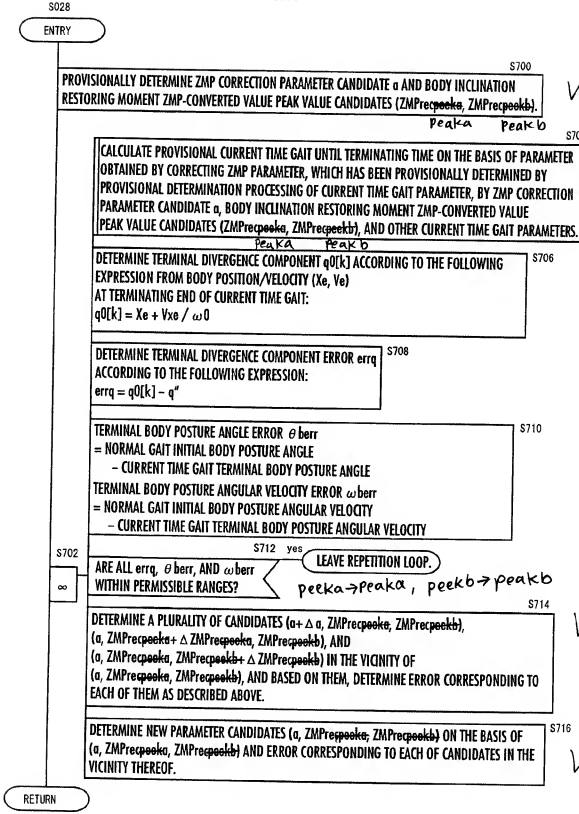

S028
ENTRY
S700
PROVISIONALLY DETERMINE ZMP CORRECTION PARAMETER CANDIDATE α AND BODY INCLINATION RESTORING MOMENT ZMP-CONVERTED VALUE PEAK VALUE CANDIDATES (ZMPrecpeeka, ZMPrecpeekb).
peaka peakb
S704
CALCULATE PROVISIONAL CURRENT TIME GAIT UNTIL TERMINATING TIME ON THE BASIS OF PARAMETER OBTAINED BY CORRECTING ZMP PARAMETER, WHICH HAS BEEN PROVISIONALLY DETERMINED BY PROVISIONAL DETERMINATION PROCESSING OF CURRENT TIME GAIT PARAMETER, BY ZMP CORRECTION PARAMETER CANDIDATE α, BODY INCLINATION RESTORING MOMENT ZMP-CONVERTED VALUE PEAK VALUE CANDIDATES (ZMPrecpeeka, ZMPrecpeekb), AND OTHER CURRENT TIME GAIT PARAMETERS.
peaka peakb
S706
DETERMINE TERMINAL DIVERGENCE COMPONENT q0[k] ACCORDING TO THE FOLLOWING EXPRESSION FROM BODY POSITION/VELOCITY (Xe, Ve) AT TERMINATING END OF CURRENT TIME GAIT:
q0[k] = Xe + Vxe / ω0
S708
DETERMINE TERMINAL DIVERGENCE COMPONENT ERROR errq ACCORDING TO THE FOLLOWING EXPRESSION:
errq = q0[k] − q''
S710
TERMINAL BODY POSTURE ANGLE ERROR θberr
= NORMAL GAIT INITIAL BODY POSTURE ANGLE
− CURRENT TIME GAIT TERMINAL BODY POSTURE ANGLE
TERMINAL BODY POSTURE ANGULAR VELOCITY ERROR ωberr
= NORMAL GAIT INITIAL BODY POSTURE ANGULAR VELOCITY
− CURRENT TIME GAIT TERMINAL BODY POSTURE ANGULAR VELOCITY
S702
∞
S712
yes
ARE ALL errq, θberr, AND ωberr WITHIN PERMISSIBLE RANGES?
LEAVE REPETITION LOOP.
peeka→peaka , peekb→peakb
S714
DETERMINE A PLURALITY OF CANDIDATES (α+Δα, ZMPrecpeeka, ZMPrecpeekb), (α, ZMPrecpeeka+Δ ZMPrecpeeka, ZMPrecpeekb), AND (α, ZMPrecpeeka, ZMPrecpeekb+Δ ZMPrecpeekb) IN THE VICINITY OF (α, ZMPrecpeeka, ZMPrecpeekb), AND BASED ON THEM, DETERMINE ERROR CORRESPONDING TO EACH OF THEM AS DESCRIBED ABOVE.
S716
DETERMINE NEW PARAMETER CANDIDATES (α, ZMPrecpeeka, ZMPrecpeekb) ON THE BASIS OF (α, ZMPrecpeeka, ZMPrecpeekb) AND ERROR CORRESPONDING TO EACH OF CANDIDATES IN THE VICINITY THEREOF.
RETURN

FIG.19

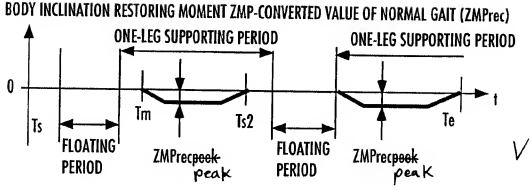
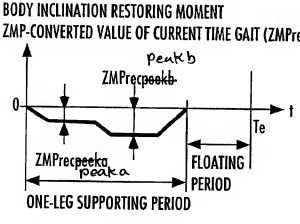

BODY INCLINATION RESTORING MOMENT ZMP-CONVERTED VALUE OF NORMAL GAIT (ZMPrec)
ONE-LEG SUPPORTING PERIOD
ONE-LEG SUPPORTING PERIOD
0
t
Ts
FLOATING PERIOD
Tm
Ts2
FLOATING PERIOD
Te
ZMPrecpeek peak
ZMPrecpeek peak

FIG.20


BODY INCLINATION RESTORING MOMENT
ZMP-CONVERTED VALUE OF CURRENT TIME GAIT (ZMPrec)
peakb
ZMPrecpeekb
0
t
Te
ZMPrecpeeka peaka
FLOATING PERIOD
ONE-LEG SUPPORTING PERIOD